Ecological Economics 145 (2018) 126–136

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Border Carbon Adjustments Based on Avoided Emissions: Addressing the Challenge of Its Design

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ARTICLE INFO

JEL Classifications:
F13, H23
Q54
Q56

Keywords:
Carbon Border Tax
Avoided Emissions
Climate Change
Global Public Good
European Union
GHG Emissions

ABSTRACT

Carbon pricing is an essential instrument to address climate change. However international differences in carbon control policies may cause not only carbon leakage but also competitiveness disadvantages. In this context, border carbon adjustments are a promising tool for discouraging these problems. But designing a real-world border carbon adjustment instrument implies to consider significant issues: technical feasibility, data availability, the risk of retaliation from developing countries, and its compatibility within the World Trade Organization legal framework. There are still no conclusive answers about a proper design. This paper is an attempt to address the above-mentioned challenges proposing a carbon border tax (CBT) based on avoided emissions. Such a CBT is applied at a product level and not at a sector level, and all international prices are deflated to guarantee that import 'like' goods received a treatment similar to 'like' domestic products. Using the WIOD, we simulate a CBT based on avoided emissions applied by the European Union, and we compare the results with a CBT based on embodied emissions.

1. Introduction

Climate change is a global problem that urgently requires global solutions. The concentration of greenhouse gases (GHGs) in the atmosphere is the product of several sources of emissions from all countries. Consequently, the climate —which affects everyone— depends on everyone's behavior.

The global nature of the problem makes the fight against climate change a global public good: the costs of abatement are national, while the benefits are global and independent of where the emission reduction is obtained. In this context, countries have the incentive to neglect environmental policies aimed at reducing domestic emissions and to rely on the reduction achieved by other countries. This is known as the free-rider problem.

Traditional solutions for public goods applied at national level cannot be effective when these goods are global. Governments have the legal authority to establish laws and institutions within their territories but there is no legal mechanism to coerce reluctant free-riding countries into international treaties or agreements that would guarantee the provision of global public goods.

Although the ideal system would be a cooperative regime in which countries negotiate a binding agreement to ensure efficient provisions of the global public good, the Westphalian nature of the current system of nations makes this cooperation unlikely, though not impossible.[1]

Theory and observation show the difficulties to design and approve effective and stable international climate agreements. In the past, the 1997 Kyoto Protocol set internationally binding emission reduction targets to signatory countries. Nevertheless, the United States (US) did not ratify the agreement and some of the signatory countries did not comply with their commitments. More recently, in December 2015, the Paris Conference of the Parties revealed again the political difficulties to adopt and implement a solution at a global level. Once again, without a system of penalties on non-participants and non-fulfillers, stable coalitions are difficult and emissions reductions are expected to

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[1] The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer is an example of a successful global agreement. However, in the fight against climate change the experience so far has been much more disappointing. The different characteristics of ozone-depleting substances and greenhouse substances mostly explain the different difficulties to act against the ozone layer problem and against global warming. In the first case, the problem was associated with particular industrial processes and substances for which there were cheap substitutes. In contrast, global warming is associated with production processes that generally characterize industrial societies, such as the use of fossil fuels, intensive agrarian and cattle sectors, or a massive generation of waste.

http://dx.doi.org/10.1016/j.ecolecon.2017.08.003
Received 24 January 2017; Received in revised form 25 July 2017; Accepted 7 August 2017
Available online 11 September 2017

be small (Nordhaus, 2015).

In short, on the one hand the global character of climate change would require a global binding agreement inherently difficult to be achieved. On the other hand the problem needs an urgent solution and cannot wait for such an agreement. Accounting for this contradiction, and considering the difficulties of collective action to face global "public bad", Elinor Ostrom (2009) defended the idea of adopting "a polycentric approach for coping with climate change". Citizens as well as local and national authorities should voluntarily change their behavior in order to contribute to reduce the problem, while waiting for such a global agreement. Ostrom's idea reflects what is happening in practice. In 2016, about 60 jurisdictions —national and subnational— had a carbon pricing instrument covering about 13% of global GHG emissions (World Bank Group, ECOFYS, 2016).

In a globalized world, however, these unilateral actions might cause two related problems: carbon leakage —i.e. an increase of emissions in countries with less stringent or no abatement policies— and a loss of competitiveness for the country implementing the environmental policy (Lockwood and Whalley, 2010; Horn and Sapir, 2013). In this context, the key issue is the need of some measures to 'level the carbon playing field' (Houser et al., 2008; Krugman, 2009). One economically well-founded measure is the so-called border carbon-motivated adjustment (BCA). With this instrument, the region that already has a carbon pricing mechanism —the abating region— imposes a 'border adjustment' or tariff on certain products imported from countries that do not limit their global warming emissions —the non-abating regions—.[2]

The carbon leakage and competitiveness are issues of concern and the debate on the viability of a BCA is in the political agenda of regions like the US (American House of Representatives, 2009) and the European Union (EU) (Mattoo et al., 2009; Kuik and Hofkes, 2010). Also international trade institutions such as World Trade Organization (WTO) have already considered the relevance of this measure (UNEP and WTO, 2009; Hillman, 2013; Mattoo and Subramanian, 2013a). However, a BCA has not been implemented thus far, partly because it gives rise to some unsolved issues. One of them is its compatibility with the international legal framework, which has become a crucial point in the debate of BCA design. In short, the general WTO philosophy refers to the so-called non-discrimination principle. Using the WTO words "the products […] imported into the territory of any […] contracting party shall not be subject […] to internal taxes […] in excess of those applied […] to like domestic products".[3]

This issue is closely related with the subject of this paper: the technical problem of computing the tax base of the tariff, which entails to define how to calculate the emissions of different products imported from different countries and, thus, how to design a BCA.

There are two general approaches to define the tax base of a BCA. The first option takes as a reference the non-abating regions —the origin or place of production of the imported good— and it is based on the total emissions embodied in the good produced in the foreign country (Mattoo et al., 2009; Mattoo and Subramanian, 2013b; Atkinson et al., 2011; Dissou and Eyland, 2011; Böhringer et al., 2012; Ghosh et al., 2012; Elliott et al., 2013; Schenker et al., 2013). In the second option, conversely, the reference is the abating region —the place of destination or consumption of the imported good— and it is based on the total emissions embodied in the good if it were produced in the importing country (Mattoo et al., 2009; Mattoo and Subramanian, 2013b; Böhringer et al., 2012; Elliott et al., 2013).

The option of a BCA based on emissions embodied in imports has been considered by many authors and it would have a positive impact in environmental terms because it introduces different taxes discriminating according the carbon emissions of different exporters. In any case, we should emphasize that the role of BCA is not to discriminate imports according their emission; its role in environmental terms is to make national carbon pricing more feasible and improve it avoiding competiveness and leakage problems.

Even more importantly, its implementation would be almost unfeasible because it is very data demanding, especially if we want to apply different taxes to different producers and not based on countries' average emissions. It would require a large amount of data about technologies and sectorial emissions in different countries, which are not available for all countries and all economic activities. Moreover, it would be very difficult to control the deviation of exports from more polluting countries using third countries (see Monjon and Quirion, 2010).

Even in the case of solving the practical problems of estimating embodied emissions, this measure could find a great opposition arguing that it infringes the two aforementioned WTO principles. Besides, even in the case of a BCA WTO-compatible design, some developing countries could manifest their reticence for its potential as a protectionism measure (Holmes et al., 2011) and they could apply trade retaliations (Fouré et al., 2016). In this context, Sakai and Barrett (2016) propose the 'best available technology' principle as an equalization measure that would avoid being challenged under WTO law. This proposal, however, is not exempted from implementation problems linked to the definition of the best technology of reference.

On the other hand, a BCA based on emissions embodied in the domestically produced good might be considered as more clearly compatible with WTO principles and it would also be less data demanding. However, in this case the problem would be the definition of the domestic technology due to the complexity of global supply chains that characterizes production processes nowadays.

In this paper we propose an innovative alternative to design a BCA based on the total —direct and indirect— emissions that the abating region would have generated if it had produced completely —i.e. in all the phases of production— all the imports from non-abating regions in its own territory. We called it a BCA based on avoided emissions and it reproduces a hypothetical autarky situation. We assume that all inputs —domestic and imported— have been produced in the abating region by applying the so-called 'domestic technology assumption' corrected for international price differences (Arto et al., 2014), i.e. we introduce the deflation of imports as an equalization measure.[4]

[2] The application of a BCA in the form of tariff could also be applied not only when the policy of the abating region is a carbon tax but also in the case of the existence of an emissions trading system (Gros and Egenhofer, 2011). However, the volatility of allowances price makes it difficult to determine which would be the proper border carbon price or tax. In this case "the requirement for importers to surrender carbon allowances is more likely to be compatible with international law than an import tax" (Kuik and Hofkes, 2010: 1742). Anyway, also in this scenario there would be a problem similar to the one related to carbon border taxes analysed in this paper: what number of allowances should the importer buy? In principle —as in the case we analyse in the paper— we could use as a reference the effective emissions generated to produce the imported good or the avoided emissions (see later). In this respect, it is the same to pay 20 euros for any ton of CO_2 in terms of taxes or in terms of buying allowances. An important difference, however, is that the carbon price to pay is not fixed in the second case but it depends of the moment in which the allowance is bought. In any case our conclusions when comparing relative economic impact and viability in the context of World Trade Organization rules of different designs of tax base could be applied for defining different amounts of required allowances. On the different problems of implementing a border adjustment with emissions trading systems, see Monjon and Quirion (2010).

[3] See articles I and III in the General Agreement on Tariffs and Trade (WTO, 1947, 1994). However, there is an important debate and a legal discussion about the interpretation of these articles. In fact the non-discrimination principle might be overcame through article XX of the same WTO text that contemplates exceptions to the non-discrimination principle (see Hillman, 2013 for a detailed discussion).

[4] Our proposal is somehow in line with the approach of Mattoo et al. (2009), Böhringer et al. (2012) and Elliott et al. (2013) who propose as a possible metric to take into account the emissions generated producing the goods within the importing country. Anyway, the previous studies do not explicitly consider that the goods produced by the importing countries use some inputs that are imported. So it is not clear how they propose to take into account the emissions generated to produce those inputs, that is the novelty of our proposal. Simply referring to the carbon content embodied in the domestically produced goods might refer to the domestic production, excluding the imported inputs, or to the emissions embodied in the imported inputs too, taking into account foreign technologies. Moreover, we take into account international prices differences. Considering all these issues we think that none of the previous solutions would guarantee the same final treatment to domestic and imported products.

The design of the BCA based on avoided emissions tries to guarantee that imported goods received a treatment similar to 'like' domestic products as the WTO framework suggests. Moreover this system has an additional advantage in terms of empirical application because it requires much less information than previous BCA systems; in particular, it only requires data about the technology and sectorial emissions from the abating country or region.

Any option based on taxing imports taking into account domestic technologies treats equally imports from countries with different technologies. In particular, it does not recognize the merit of foreign producers who use technologies cleaner than domestic ones. However, the problem is not the existence of a border tax but the inexistence of a global carbon tax. In the absence of carbon taxes the environmental merits of cleaner technologies are not recognized because enterprises do not pay for climate change costs. In any case, it could be possible to introduce the possibility for exporters to claim that their total (direct and indirect) emissions for producing a specific product are lower than the emissions used to define the tax and to benefit from tax discounts.

We take the EU as a case study; we assume that the EU applies a BCA on imports in the form of a tax to compensate a European CO_2 tax and, at the same time, that the EU exempts its exports from the domestic carbon tax (Holzer, 2010). Moreover, unlike the existing literature, the taxes and the BCA are applied at a product level and not at a sector level. Data from the World Input Output Database (WIOD) and COMEXT database are used in this simulation.

The analysis provides results at a product and country level. In this way it shows not only the incidence of different BCA designs through the average effect for each country, but also the spread or concentration of BCA designs among the different products imported from different countries. It would be also relevant to take into account the reaction of economic agents to prices changes as well as other substitution effects after the introduction of a BCA. However, the aim of our analysis is to address the problem of the design of a BCA, and in particular the computation of its tax base, what is called the metric problem. In that sense, the analysis of total economic effects of the implementation of a BCA is beyond the scope of this paper.

The paper is structured as follows. Section 2 provides the methodology. Sections 3 and 4 describe the data and results, respectively. Finally, Section 5 concludes.

2. Methodology

Imagine an abating region that applies unilaterally a domestic carbon price. In this context, we further assume that this region exempts its exports from the domestic carbon price to avoid the competitive disadvantage of domestic firms in the world market, and that it also implements a carbon border tax (CBT) on imported products to avoid the competitive disadvantage of domestic firms in the domestic market. Likewise we also assume that non-abating regions do not implement any emissions reduction policy or, if they do, they also exempt their exports from it.

We consider two alternatives for the design of such tariff: one based on the actual emissions produced by the non-abating regions —i.e. a CBT based on embodied emissions (EE-CBT)—; and another based on the emissions that the abating region would have produced in autarky —i.e. a CBT based on avoided emissions (AE-CBT)—. The design of the AE-CBT tries to guarantee that imported goods received a treatment similar to 'like' domestic products as the WTO framework suggests.

2.1. CBT on Embodied Emissions

The EE-CBT is our benchmark and takes into account the fact that production processes are often global and emissions generated in each stage of production are produced in different places with different technologies and, in consequence, different emission intensities.

In this context, the tariffs $\boldsymbol{\tau}_{\mathbf{EE}}$ applied to each imported product depends on the carbon price that the abating region applies to the carbon content of domestic products —i.e. the tax rate t— and the embodied emissions per monetary unit of imported product —i.e. the tax base $\tilde{\mathbf{e}}_{\mathbf{EE}}$—, according to the following expression[5]:

$$\tau_{EE} = t\,\tilde{e}_{EE} \tag{1}$$

To calculate emissions embodied in imported products ($\tilde{\mathbf{e}}_{\mathbf{EE}}$) we use a multi-regional multi-sectoral framework. Let us consider a world consisting of c countries, each composed of n sectors, in which sectoral deliveries are represented by z_{ij}^{rs} that shows the amount of output from sector i in country r consumed as intermediate input by sector j in country s in value terms. Besides, each sector generates a certain amount of emissions v_j^s.

The input structure or technology of the world is represented by matrix $\mathbf{A}$, where each element $a_{ij}^{rs} = z_{ij}^{rs}/x_j^s$ indicates the input from industry i in country r per unit of output of industry j in country s (being x_j^s the value of total output of sector j in country s). In the same way, emission intensities by sector are $e_j^s = v_j^s/x_j^s$.

If we multiply imports by these direct emissions coefficients of the corresponding producer country (as in Mathiesen and Maestad, 2004; Kuik and Hofkes, 2010; Lin and Li, 2011; and Burniaux et al., 2013), the emissions embodied in imports would be underestimated because direct coefficients ignore the pollution generated by all intermediate inputs —the direct ones but also those used to produce these inputs—. So, to calculate direct and indirect emissions embodied in imports we rely on total emission multiplier from the standard multiregional input-output framework.[6] We apply the expression $\mathbf{G} = \hat{\mathbf{e}}\mathbf{L}$, in which matrix $\mathbf{L}$ is the Leontief inverse ($\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$), and $\mathbf{e}$ is the vector of emission intensities by sector. Each element g_{ij}^{rs} of matrix $\mathbf{G}$ reveals total emissions that sector i of country r produces for an additional unit of sector j in country s.

However, the CBT should be applied at a product level. Then, considering that there are m products and that each sector can produce different products, emissions embodied in imported products $\tilde{\mathbf{e}}_{\mathbf{EE}}$ are equal to $\tilde{\mathbf{e}}_{\mathbf{EE}} = \mathbf{i}'\mathbf{GU}$. Where $\mathbf{U}$ is a diagonal block matrix of dimension $[(n \times c) \times (m \times c)]$ that links sectors to products and its element u_{ik}^{rs} shows the share of product k of country s produced by sector i in country r.

2.2. CBT on Avoided Emissions

A similar procedure is necessary for estimating the tariff $\boldsymbol{\tau}_{\mathbf{AE}}$ applied to each imported product based on the avoided emission method:

$$\boldsymbol{\tau}_{\mathbf{AE}} = \widehat{t_{AE}}\,\tilde{\mathbf{e}}_{\mathbf{AE}} \tag{2}$$

In this case, the tax base $\tilde{\mathbf{e}}_{\mathbf{AE}}$ accounts for total emissions contained in a hypothetically identical product produced entirely in the abating region —i.e. as if the imported product had been produced fully at home accounting in that way for the emissions avoided by importing goods—.

We consider, then, that the abating region operates in autarky. For this purpose, we apply the domestic technology assumption corrected for international price differences (see Arto et al., 2014).

In this context, total —direct and indirect— emissions by sector are calculated by $\mathbf{G}_{\mathbf{AE}} = \widehat{\mathbf{e}_{\mathbf{AE}}}\mathbf{L}_{\mathbf{AE}}$, where $\mathbf{e}_{\mathbf{AE}}$ is the vector of emissions intensities for the abating region and $\mathbf{L}_{\mathbf{AE}}$ is the Leontief inverse derived from the matrix of total input coefficients of the region ($\mathbf{L}_{\mathbf{AE}} = (\mathbf{I} - \mathbf{A}_{\mathbf{t}})^{-1}$). Matrix $\mathbf{A}_{\mathbf{t}}$ represents the technology of the abating region

[5] Matrices are indicated by bold, upright capital letters; vectors by bold, upright lower case letters; scalars by italicized lower case letters. Vectors are columns by definition, so that row vectors are obtained by transposition, indicated by a prime. A circumflex indicate that we have transformed the vector into a diagonal matrix with the elements of the vector on its main diagonal and all other entries equal to zero. The notation $\mathbf{i}$ is used to represent a column vector of 1's of appropriate dimensions, and $\mathbf{I}$ is the identity matrix.

[6] See Miller and Blair (2009).

in autarky; thus, if matrix $\mathbf{A_t}$ comes from the aggregation of domestic and imported inputs expressed in monetary terms, price differences across countries should be taken into account by applying a monetary deflator. In this case, each imported product k used as intermediate input is deflated using the ratio between foreign and domestic price $p_k{}^s/p_k{}^r$, which are the elements of the deflator vector $\mathbf{d_{AE}}$.[7]

As in the EE-CBT system, emissions by product are calculated as $\tilde{\mathbf{e}}_{\mathbf{AE}} = \mathbf{i}'\mathbf{G_{AE}}\mathbf{U_{AE}}$, where $\mathbf{U_{AE}}$ is a $(n \times m)$ matrix showing the share of any product k produced by any sector i of the abating region.

Finally, to obtain tariffs ($\boldsymbol{\tau}_{\mathbf{AE}}$) in the AE-CBT system, we define the tax rate vector $\mathbf{t_{AE}}$ as $\mathbf{t_{AE}} = t\mathbf{d_{AE}}$. In this expression, t is the carbon price already applied to the carbon content of domestic products by the abating region, and $\mathbf{d_{AE}}$ is the deflator vector that allows for deflating the monetary value of the imported product. This second deflation is important to guarantee that imported goods received a treatment similar to 'like' domestic products as the WTO framework suggests.

3. Data

All estimations have been made using data for the year 2009 from WIOD (Genty, 2012; WIOD, 2012, 2013; Timmer et al., 2015) and COMEXT (Eurostat, 2015).

From the WIOD we use a multi-regional input-output table, international supply and use tables, and CO_2 emissions data for the year 2009. First, we use the multi-regional input-output table at current prices to compute the EE-CBT. This industry by industry table offers information for 41 countries (27 countries of the EU27, 13 other major countries in the world, and all the remaining countries aggregated in a single "rest of the world" region) and 35 sectors. Second, we use the international supply and use tables to compute the AE-CBT. In this case, we aggregate the 27 countries of the EU into one single region —the EU27— using the information from the remaining 14 countries to determine the imported intermediate inputs of each sector. We also use the international supply and use tables to compute matrices $\mathbf{U}$ and $\mathbf{U_R}$, which allow to bridge information from 59 CPA products and 35 NACE sectors. Finally, we use data on CO_2 emissions (in 1000 tons) by sector from the air emissions accounts, which have the same sector breakdown (35 sectors) and geographical coverage (41 countries) as the multi-regional input-output table.

COMEXT contains statistics on trade among EU countries, and between EU countries and non-EU countries. Data are expressed in monetary terms (euro) as well as in physical terms (kilograms), which allow us to calculate the deflators.[8] In particular, from a total of 283 trading countries and 881 products available in COMEXT, we use information on the 13 non-EU countries and "rest of the world" considered in WIOD and on 217 manufactured products aggregated into 22 WIOD categories.

We omit agricultural products, raw materials and services imported by the EU in our analysis. First, we exclude agricultural products and raw materials because for some products of these categories import is the only way to provide these products to the European market. Two clear examples are cocoa beans to produce chocolate and coltan to manufacture electronic devices. Moreover, the data disaggregation available does not permit to distinguish between products imported by the EU because they are not producible domestically from products imported but also producible inside the EU. Second, we exclude services because we consider a CBT system of customs duties applied exclusively to products physically imported.[9]

As a result, the CBT rates are calculated for 308 products (22 categories multiplied by the 13 non-EU countries plus the "rest of the world" from WIOD). These tax rates are average tariffs, assuming a unique homogeneous good for each WIOD classification, which aggregates a wide variety of products.

4. Results

We take the EU as a case study due to its leading role on carbon pricing (Gros and Egenhofer, 2011) and because there is a current debate on strengthening its environmental policies —the European Emissions Trading System (European Parliament and Council, 2003) and the European Energy Tax Directive (European Council, 2003)— to reach the EU's challenging targets of emission reduction, in particular in the new framework of the Paris agreement.

We consider the EU as a single region and we assume that it has a domestic carbon tax of 20 euro/tonCO_2 applied to all sectors. This tax level was in fact the tax rate proposed, but not approved, for non-emission trade sectors by the European Commission to reform the European Energy Tax Directive (European Commission, 2011; Rocchi et al., 2014).[10] As the literature suggests, we also assume that the EU exempt their exports from the domestic carbon taxation to avoid the competitive disadvantage of domestic firms in the world market (Holzer, 2010). Likewise we presume that non-EU countries are not implementing any emissions reduction policy or, if they do, they exempt their exports from it. Then, in order to 'level the carbon field' we simulate a hypothetical CBT that the EU would apply on products imported from non-EU countries. Tariffs are computed based on an AE-CBT system and we compare the results with tariffs based on an EE-CBT system, our benchmark.

Table 1 shows AE-CBT tariffs by product for each non-EU country. Emissions avoided by the EU when it imports a physical unit of a product are the same independently of the country from which the product is imported; however, tariffs in Table 1 —expressed as percentages of monetary values— vary among countries due to international differences in prices. As this table shows, the products mostly affected would be those goods whose production in the EU is very energy intensive such as 'other non-metallic mineral products' (26)[11] —which comprise the production of cement, ceramics, glass, and lime—; 'coke, refined petroleum products' (23) —based on the transformation of crude petroleum and coal into usable products—; and 'chemical products' (24) —including petrochemicals, polymers, basic inorganics, specialties, and consumer chemicals—. From these three categories, 'other non-metallic mineral products' (26) would be the most affected, particularly products imported from Russia (with a tariff rate of 7.8%), China (7.6%) and Indonesia (6.1%). For 'coke, refined petroleum products', the rates would be substantially high for Mexico (16.8%) and Australia (10.2%). Finally, for 'chemicals, chemical products', the most affected country would be Indonesia (8.1%). The remaining 19 product categories would have a (non-weighted) country average rate smaller than 2%.

Anyway, tariffs of the AE-CBT system are on average significantly lower than those of the EE-CBT. Fig. 1 presents results at aggregate level, showing that products affected by tariffs higher than 2% in a AE-CBT system (Fig. 1a) would be less than half of those in a EE-CBT system (Fig. 1b); conversely, products affected by tariffs less than 1%

[7] To properly deflate imported inputs, $\mathbf{A_t}$ should be derived from supply and use tables. The use table should be previously deflated using the vector $\mathbf{d_{AE}}$.

[8] Table A.1 from the Appendix provides the deflators calculated in this study.

[9] It would be relevant to extend the analysis including the agricultural products and raw materials that are producible and/or produced in the EU, but this would require data more disaggregated than the ones available in the used database. Including the analysis of agricultural products and raw material would probably affect the results of our analysis, mainly for Brazil and US.

[10] Although we set the carbon taxation at a specific value of 20 euro/tonCO_2 —which would be more or less equivalent a 7–8 euro tax for a crude oil barrel— to interpret our results more easily, the analysis could be expressed in a general form for any tax level t. As tax rates are a linear transformation of the emission content of each product, rates in a general form can be obtained by multiplying the results obtained by $t/20$. Moreover, this tax rate would be considered moderate since several authors have recently proposed that the adequate level of a carbon tax should be higher than 100 US\$/tonCO_2 —approximately 95euro/tonCO_2— (see, for instance van den Bergh and Botzen, 2014).

[11] The number in parentheses after a product name refers to the product's number in Table 1.

Table 1
CBT rates on avoided emissions, by product and country, 2009.
Source: own elaboration.

WIOD code	WIOD product	AUS	BRA	CAN	CHN	IDN	IND	JPN	KOR	MEX	RUS	TUR	TWN	US	RoW
15	Food products and beverages	1.0	1.6	0.5	0.6	1.8	0.8	0.3	0.5	0.8	1.7	0.7	1.2	0.9	1.0
16	Tobacco products	0.8	2.3	0.4	0.5	3.8	3.0	1.4	1.0	0.5	1.0	0.7	0.8	0.9	2.2
17	Textiles	0.7	1.2	1.5	2.1	2.5	1.6	0.5	1.3	1.2	2.0	1.4	1.5	0.8	2.0
18	Wearing apparel	0.7	1.0	0.4	1.5	1.0	1.4	0.2	1.4	0.6	0.8	0.9	1.7	0.7	1.3
19	Leather and leather products	1.8	0.9	0.9	2.6	1.0	1.1	0.3	0.7	0.8	1.4	1.2	1.4	1.1	1.1
20	Wood and products of wood and cork	0.8	0.8	0.9	0.9	0.6	0.7	0.2	0.3	0.3	1.3	0.6	0.4	0.6	0.9
21	Pulp, paper and paper products	0.7	0.8	0.7	0.5	0.6	0.6	0.1	0.5	0.7	0.7	0.8	0.3	0.5	0.7
22	Printed matter and recorded media	0.6	0.5	0.4	1.9	2.6	2.3	0.3	1.5	0.3	0.7	1.5	0.8	0.5	1.2
23	Coke, refined petroleum products	10.2	2.8	3.2	1.2	1.7	1.8	1.8	1.8	16.8	2.0	1.6	1.9	2.9	2.0
24	Chemicals, chemical products	1.0	3.5	1.3	2.5	8.1	2.4	0.4	2.2	2.3	3.3	2.6	1.6	0.8	1.5
25	Rubber and plastic products	0.5	0.7	0.8	1.4	1.1	1.3	0.4	0.8	0.6	0.7	1.0	0.9	0.4	1.0
26	Other non-metallic mineral products	1.4	3.6	4.4	7.6	6.1	4.7	0.7	1.6	3.3	7.8	4.9	4.2	1.3	6.4
27	Basic metals	0.5	1.1	0.3	1.7	0.5	1.7	0.6	0.9	1.2	1.3	2.0	1.3	0.9	0.7
28	Fabricated metal products	1.0	1.9	1.1	3.2	2.3	3.0	0.9	2.2	1.4	3.0	2.6	2.9	0.7	1.5
29	Machinery and equipment n.e.c.	0.5	1.1	0.4	1.7	1.3	1.4	0.5	1.1	0.7	1.2	1.4	1.1	0.5	0.6
30	Office machinery and computers	0.2	0.4	0.3	0.7	1.4	1.1	0.3	0.3	0.3	0.3	0.6	0.4	0.4	0.4
31	Electrical machinery	0.2	1.3	0.2	1.2	1.0	1.3	0.3	0.6	0.4	1.1	1.2	0.5	0.2	0.6
32	Radio, television and comm. eq.	0.7	1.3	0.4	1.4	0.7	2.2	0.7	0.5	0.4	0.8	1.0	0.7	0.6	1.1
33	Medical and optical instruments	0.3	1.2	0.5	4.2	0.8	1.9	0.5	1.3	0.8	0.2	3.1	1.6	0.4	0.5
34	Motor vehicles, trailers	0.4	0.7	0.6	1.6	0.8	0.9	0.5	0.9	0.6	1.0	0.7	0.9	0.5	0.8
35	Other transport equipment	1.0	0.6	0.9	1.1	2.2	1.5	0.6	0.2	1.6	3.1	0.8	0.9	0.8	0.4
36	Furniture; other manufactured goods	0.2	8.7	0.4	1.6	1.6	0.9	0.4	1.0	1.2	0.7	1.2	1.2	0.7	1.1

Unit: percentage.
Non-EU countries: AUS: Australia; BRA: Brazil; CAN: Canada; CHN: China; IDN: Indonesia; IND: India; JPN: Japan; KOR: Korea; MEX: Mexico; RUS: Russia; TUR: Turkey; TWN: Taiwan; US: United States; RoW: Rest of the World.

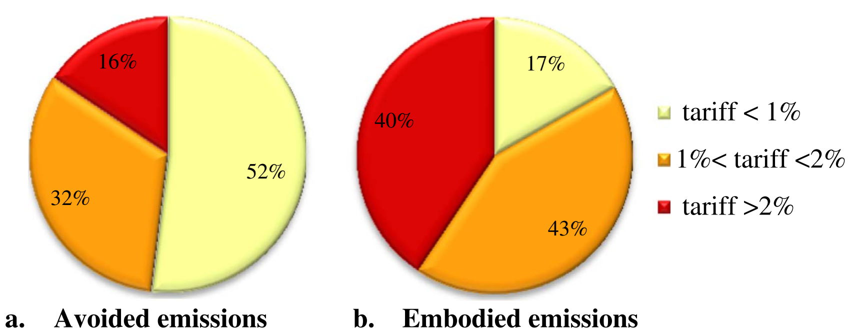

Fig. 1. Percentage of products based on the tariff size.
Source: own elaboration.

would be three time higher.[12]

These differences are due basically to three countries: China, India, and Russia (see Fig. A.1 from Appendix). For these countries only 27% of products would be greatly affected considering an AE-CBT and the (non-weighted) product average tariffs would be 1.9% (China), 1.7% (India), and 1.6% (Russia). Considering an EE-CBT, 100% of their products would be charged at tariffs higher than 2%, and the (non-weighted) tariff average would be, respectively, 3.9%, 4.9%, and 4.9%. Although in a less decisive way, for almost all the other countries, an AE-CBT system would also have a weaker impact than an EE-CBT in terms of both the level of the tax rates and their spread across products.

These results suggest that the technology of the EU is in most cases less polluting than the technology of the countries from which the EU imports goods, i.e. the emissions would be smaller if the EU had produced domestically all its imports and in the same quantities. The only products that would be taxed more with the AE-CBT system, and therefore more 'polluting', would be 'tobacco products' (16) imported from Brazil, Indonesia, and Japan; 'textiles' (17) from Brazil, Indonesia, and Turkey; 'leather products' (19) from Austria, Canada, and Turkey; and 'chemical products' (24) imported from Brazil, Indonesia, and Turkey. All these products represent 15% of all products analysed (42 out 308)[13] (see Table A.2 from Appendix).

However, the effect of a CBT system would depend not only on the tax rate but also on the volume trade.[14] Fig. 2 shows the 20 products most affected by an AE-CBT, which represent more than 60% of the total effect of the policy.[15] Taking into account total value of imported manufactured products, the most affected country would be China —which accounts for roughly 30% of total tariff payments— followed by the US. In the case of China, the ranking of these products seems to be more closely related to the volume of trade than to the severity of the tax rates imposed. The three most affected products, for example,

[12] We also made a similar comparison of the results obtained for a system based on avoided emissions, considering data in monetary terms without taking into account international differences in prices —i.e. without deflating—; the comparison shows the bias that would result from not considering international price differences. Taxes applied to monetary unity of imported product would be in general significantly lower than the ones obtained here.

[13] In consequence, in our case study the possible "excessive" taxation of relative cleaner products does not seem very relevant. In any case —as we have said in the introduction— it would be possible to treat these cases introducing some tax discounts.

[14] We made a static quantification of the policy effect taking into account the actual size of trade flows —i.e. considering that the trade flows were not altered by the policy—. The assumption is not realistic even though in the case of avoided emissions approach the simultaneous introduction of a domestic tax and a tariff on imports does not alter, in principle, relative prices between domestic and foreign products.

[15] The region that would actually be more affected by a CBT system is the region "Rest of the World", which would pay roughly 40% of total tariff payments. However, we do not analyse this region in detail because it aggregates several and different countries, and it would not be possible to provide a more detailed explanation for the results found.

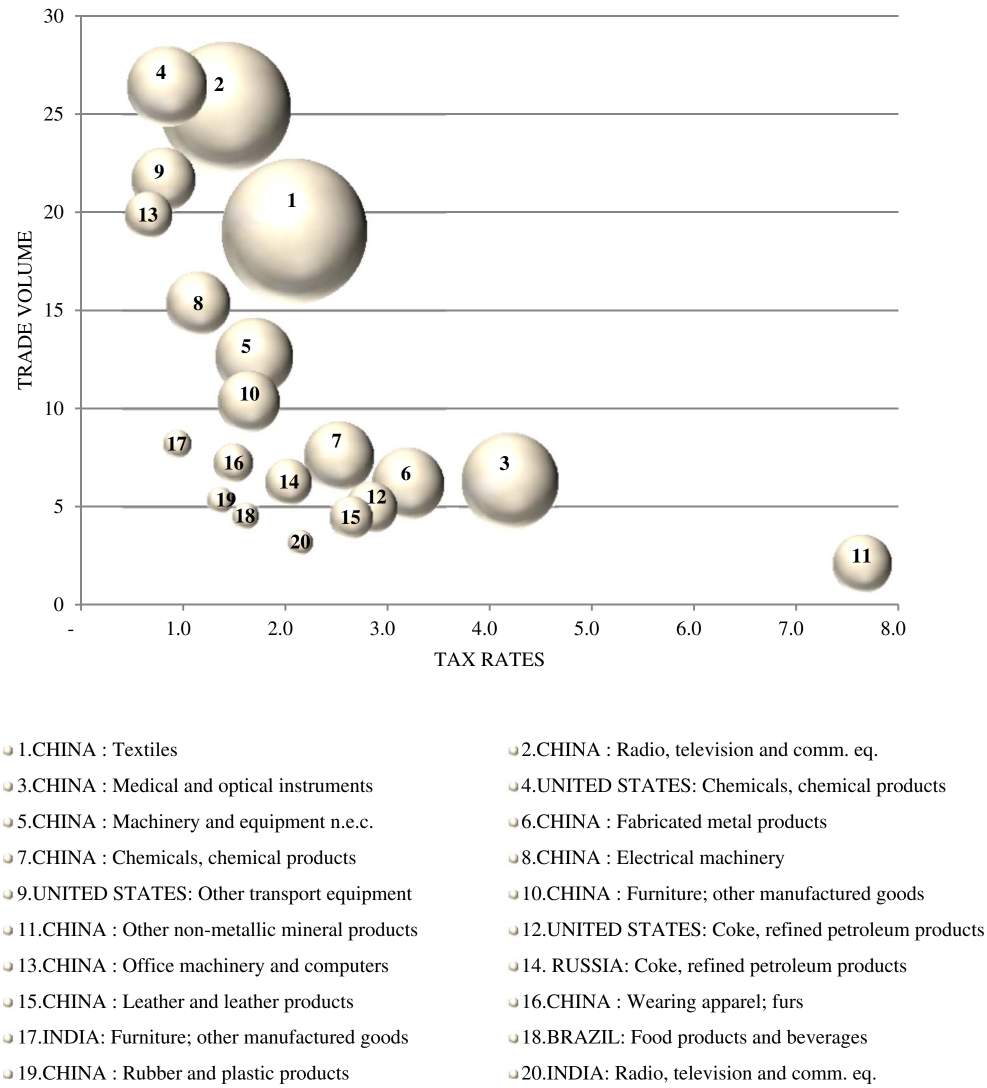

Fig. 2. The 20 products most affected by CBT on avoided emissions, 2009
Units: Trade volume in billions of euro; tax rates in percentage.
Source: own elaboration.

Units: Trade volume in billions of euro; tax rates in percentage.
Source: own elaboration.

would not be energy-intensive products, but 'textiles' (17), 'radio, television, and communications equipment' (32), and 'medical and optical instruments' (33). Two of the 20 most affected products would be from the US. In particular, US 'chemical products' (24) would be the fourth most affected product and US 'other transport equipment' (35) the ninth. Also, in this case it is due more to the volume of trade than to high tariffs (0.8% in both cases). Conversely, very high tax rates more than the trade volume explain the cost the reform would imply for Chinese products classified as 'other non-metallic mineral products' (26).

Because the impact on a CBT system relies more on the volume of trade than on the severity of the tariffs imposed, the ranking of the most affected products would change only partially in an EE-CBT system (see Fig. A.2 from Appendix). However, the two systems would imply a strongly different impact for some products: 'basic metals' (27) produced in Russia —which goes from bearing 1.1% of total policy impact under the avoided emissions system to 4.4% under a system of embodied emissions— and Chinese 'medical and optical instruments' (33) —that goes from 1.6% to 4.6%—.

In this scenario, the overall tax collection of this environmental policy based on a AE-CBT system would amount to 13 billion euros, of which nearly 70% would correspond basically to imports from developing countries —the Rest of the World (RoW) (38%), China (29%), and Turkey (5%)— only the US (9%) would the only developed country that would contribute more than 5% to the total amount (first column of Table 2). However, as the second column of Table 2 shows, these costs would represent a limited share —less than 2% in all countries— if we consider the total value of manufactured products that each non-EU country exports to the EU. In this case, percentages for the RoW, China and the US would be, respectively, 1.3%, 1.7% and 0.8%. In any country, the cost of the AE-CBT imposed by the EU would not imply more than 0.11% of its gross domestic product (third column of Table 2).[16]

5. Conclusion

Carbon pricing is an essential piece in the fight against climate change. Although a significant progress has been made over the last decade, the effort is still insufficient. Most emissions are still unpriced and applied prices in different countries and sectors vary widely. In this context, a BCA could be a measure to offset the competitiveness pressure of imports from countries with a smaller or non-existent carbon

[16] For results based on EE-CBT see Table A.3 from Appendix.

Table 2
Cost of the CBT applied by the EU for each non-EU country considering avoided emissions, 2009.
Source: own elaboration.

Non-EU country	Country's share of AE-CBT's total collection		Percentage of the value of manufactures exported by any non-EU to the EU		Percentage of the gross domestic product of each country	
Australia	0.5	[14]	1.1	[8]	0.01	[14]
Brazil	2.4	[9]	1.7	[4]	0.02	[9]
Canada	0.9	[12]	0.9	[10]	0.01	[10]
China	29.1	[2]	1.7	[3]	0.08	[2]
Indonesia	1.5	[11]	1.9	[1]	0.04	[7]
India	3.9	[5]	1.4	[5]	0.04	[5]
Japan	2.6	[7]	0.6	[14]	0.01	[13]
Korea	2.4	[8]	0.7	[13]	0.04	[6]
Mexico	0.5	[13]	0.8	[11]	0.01	[11]
Russia	2.9	[6]	1.8	[2]	0.03	[8]
Turkey	4.9	[4]	1.4	[6]	0.11	[1]
Taiwan	1.6	[10]	1.1	[9]	0.06	[4]
United States	8.8	[3]	0.8	[12]	0.01	[12]
Rest of World	38	[1]	1.3	[7]	0.07	[3]

Unit: percentage.
Note: Countries ranking: [1] is the most affected country, [14] is the less affected.

price.

There are still no conclusive answers for a proper BCA design. The BCA design should consider not only its technical feasibility and data availability, but also the compatibility with the WTO legal framework and the risk of retaliation from developing countries.

This paper contributes to the existing literature on BCA design by proposing a BCA based on avoided emissions in which we take into account international price differences. Unlike previous analyses, we apply the BCA based on avoided emission at a product and not at a sector level. Moreover, our proposal includes that all exports should be exempted from their respective national carbon price. In that way, the avoided emission system would guarantee that imported goods receive the same treatment as domestic products in line with the WTO philosophy. The avoided emission system would also be more feasible since it only requires national information about technology and emissions.

In this paper we simulate two possible CBTs applied by the EU: one based on embodied emissions (EE-CBT) —the most commonly analysed in the literature— and the other on avoided emissions (AE-CBT). The comparison of results shows that an AE-CBT would imply a smaller impact for most of the countries analysed, particularly for developing countries such as China and India. In that sense, a system based on avoided emissions may minimize the possible retaliation actions. Additionally, complementary mechanisms can be applied to make it clearer that border adjustments are not measures of protectionism and they are not aimed at raising public revenues. Mattoo and Subramanian (2013a) proposed to implement the BCA on the border of the exporter country and van den Bergh (2016) to return the BCA revenue to the affected country.

In terms of analysis by product, two groups of goods would be most affected: energy-intensive products —due to their carbon content — and electronic products —due to the large money value traded with the EU—. These results might suggest limiting the BCA system only to certain products for instance to those most exposed to the risk of leakage.

One of the essential elements of the Paris Agreement is that all parties are required to make their best effort through the so-called ‘national determined contributions’. In other words, countries will decide individually not only their emissions goals but also their mitigation policies. Thus, this agreement does not include any global carbon pricing. However, the fact is that carbon pricing is progressing in many countries. In a world where products are constantly traveling from one country to another, the international coordination of carbon pricing and also the problem of competitiveness will be more complex. In this scenario, the BCA based on avoided emissions would guarantee that every imported good would receive a treatment similar to the ‘like’ domestic one, regardless the number of frontiers the product will cross.

Acknowledgements

This work was supported by the Spanish Ministry of Economy and Competitiveness [grant numbers ECO2015-67524-R, ECO2015-68023, and HAR2015-69620-C2-1-P]; and the AGAUR of Catalonia's Government [grant number 2014SGR-950]. We thank the two anonymous referees for their many insightful comments and suggestions.

Appendix A

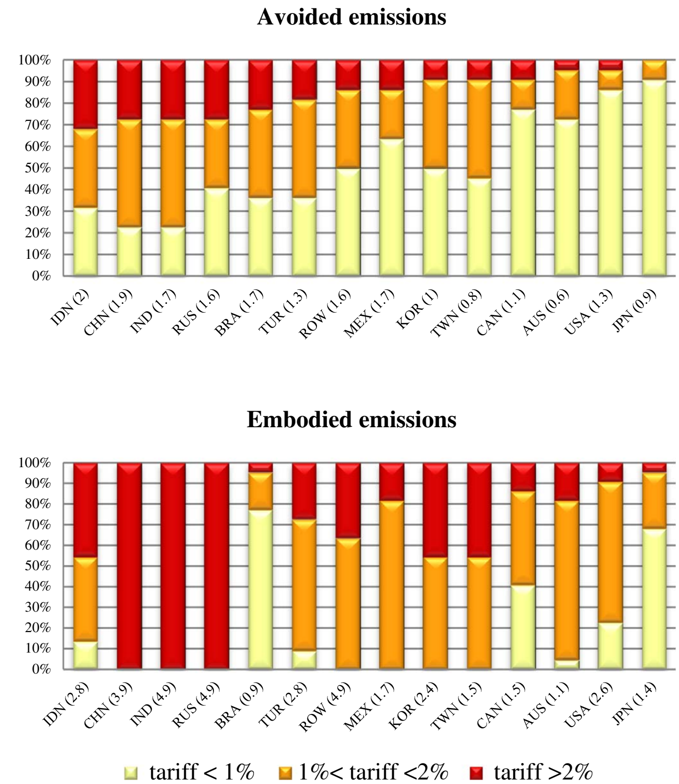

Fig. A.1. Percentage of products based on the rate by country, 2009
Note: the averages in parenthesis are computed as simple averages without taking into account trade volumes.
Source: own elaboration.

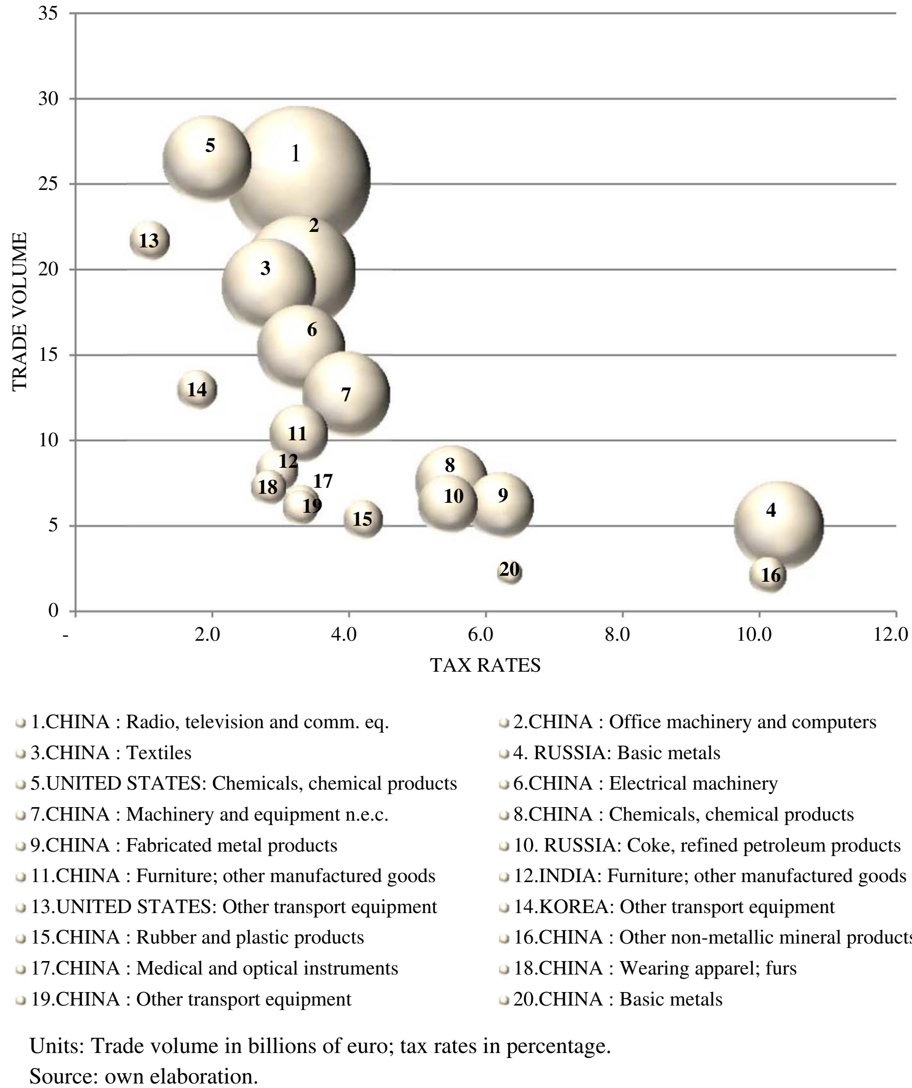

Fig. A.2. 20 products most affected by CBT on embodied emissions, 2009
Units: Trade volume in billions of euro; tax rates in percentage.
Source: own elaboration.

Table A.1
Deflators used to take into account international price differences to estimate the EU avoided emissions, 2009.
Source: own elaboration from WIOD (2013), Eurostat (2015) and Timmer et al. (2015).

	Product	AUS	BRA	CAN	CHN	IDN	IND	JPN	KOR	MX	RUS	TUR	TWN	US	RoW
15	Food products and beverages	1.3	2.1	0.6	0.8	2.3	1.0	0.4	0.6	1.0	2.2	0.9	1.5	1.1	1.3
16	Tobacco products*	1.0	3.0	0.6	0.7	4.9	3.8	1.8	1.3	0.6	1.3	0.9	1.0	1.1	2.9
17	Textiles	1.0	1.7	2.1	3.0	3.7	2.4	0.7	1.8	1.7	2.9	2.1	2.2	1.2	2.9
18	Wearing apparel	1.0	1.6	0.6	2.2	1.5	2.1	0.3	2.0	0.9	1.2	1.4	2.5	1.0	1.9
19	Leather and leather products	3.5	1.8	1.9	5.3	2.1	2.2	0.5	1.3	1.6	2.9	2.4	2.8	2.1	2.1
20	Wood and products of wood and cork	1.1	1.0	1.2	1.2	0.8	1.0	0.3	0.4	0.4	1.8	0.8	0.5	0.8	1.3
21	Pulp, paper and paper products	1.0	1.1	0.9	0.7	0.8	0.8	0.2	0.6	1.0	1.0	1.1	0.4	0.7	0.9
22	Printed matter and recorded media	0.8	0.7	0.6	2.7	3.7	3.2	0.4	2.0	0.5	1.0	2.1	1.1	0.8	1.6
23	Coke, refined petroleum products	5.3	1.4	1.6	0.6	0.9	0.9	0.9	0.9	8.7	1.1	0.8	1.0	1.5	1.0
24	Chemicals, chemical products	0.9	3.2	1.2	2.3	7.4	2.2	0.4	2.0	2.1	3.0	2.4	1.5	0.8	1.4
25	Rubber and plastic products	0.7	1.0	1.1	1.9	1.5	1.8	0.6	1.1	0.9	0.9	1.4	1.2	0.6	1.4
26	Other non-metallic mineral products	0.5	1.3	1.5	2.7	2.1	1.6	0.3	0.5	1.1	2.7	1.7	1.5	0.4	2.2
27	Basic metals	0.4	0.9	0.2	1.4	0.4	1.4	0.5	0.7	1.0	1.1	1.6	1.1	0.7	0.6
28	Fabricated metal products	0.8	1.6	0.9	2.6	1.9	2.5	0.8	1.8	1.2	2.5	2.1	2.3	0.5	1.2
29	Machinery and equipment n.e.c.	0.9	1.9	0.7	2.9	2.3	2.4	0.9	1.9	1.1	2.0	2.5	2.0	0.8	1.0
30	Office machinery and computers	0.4	0.9	0.6	1.4	3.1	2.4	0.7	0.7	0.7	0.6	1.3	0.9	0.8	0.9
31	Electrical machinery	0.4	2.4	0.4	2.2	2.0	2.4	0.6	1.2	0.8	2.0	2.2	0.9	0.4	1.1

32	Radio, television and comm. eq.	1.4	2.7	0.7	2.9	1.5	4.5	1.5	1.1	0.8	1.7	2.2	1.4	1.3	2.2
33	Medical and optical instruments	0.6	2.5	1.0	8.4	1.6	3.7	1.0	2.6	1.6	0.4	6.2	3.1	0.8	1.0
34	Motor vehicles, trailers	0.7	1.2	1.0	2.7	1.4	1.6	0.9	1.5	1.0	1.7	1.2	1.5	0.9	1.3
35	Other transport equipment	1.7	1.0	1.4	1.8	3.6	2.5	1.1	0.3	2.6	5.1	1.4	1.5	1.3	0.7
36	Furniture; other manufactured goods	0.2	13.4	0.6	2.5	2.4	1.4	0.6	1.6	1.8	1.1	1.8	1.9	1.1	1.7

Non-EU countries: AUS: Australia; BRA: Brazil; CAN: Canada; CHN: China; IDN: Indonesia; IND: India; JPN: Japan; KOR: Korea; MEX: Mexico; RUS: Russia; TUR: Turkey; TWN: Taiwan; US: United States; RoW: Rest of the World.

* The category "tobacco products" has been adjusted using additional more disaggregated data from the COMEXT database "EU Trade Since 1988 By SITC", following the nomenclature correspondence provided by Eurostat in the database RAMON available at http://ec.europa.eu/eurostat/ramon/relations/index.cfm?TargetUrl=LST_REL.

Table A.2
CBT rates on embodied emissions, by product and country, 2009.
Source: own elaboration.

		AUS	BRA	CAN	CHN	IDN	IND	JPN	KOR	MEX	RUS	TUR	TWN	US	RoW
15	Food products and beverages	1.1	1.1	1.2	1.1	1.1	1.2	1.1	1.6	1.6	2.1	2.1	1.6	1.9	2.1
16	Tobacco products	1.0	2.1	2.0	1.5	4.1	2.2	2.6	2.1	2.6	2.7	2.1	7.4	4.1	4.1
17	Textiles	1.7	0.9	1.3	1.4	1.3	1.2	1.2	1.9	1.7	1.7	1.7	1.7	1.8	1.8
18	Wearing apparel	1.3	0.7	0.7	0.6	0.6	0.5	0.5	1.9	1.1	1.1	1.6	1.6	1.1	1.4
19	Leather and leather products	0.7	0.7	1.4	1.1	0.8	3.2	1.6	1.4	1.4	3.2	1.7	1.6	5.2	2.3
20	Wood and products of wood and cork	1.6	0.8	0.8	0.8	0.8	0.8	0.7	2.2	1.3	1.6	1.6	1.6	1.6	1.1
21	Pulp, paper and paper products	0.7	0.6	1.0	1.0	1.2	1.0	0.9	1.1	1.7	2.2	2.2	2.6	2.6	2.7
22	Printed matter and recorded media	1.1	1.1	1.0	3.4	2.2	1.2	2.9	3.3	3.1	3.1	5.4	9.5	4.5	12.8
23	Coke, refined petroleum products	2.0	1.9	1.1	1.0	1.0	1.0	1.0	10.3	10.3	4.5	4.3	4.3	4.3	4.3
24	Chemicals, chemical products	1.0	1.0	1.0	2.0	2.0	2.8	2.8	3.4	3.4	4.1	1.2	1.2	1.1	1.1
25	Rubber and plastic products	2.1	2.9	3.9	3.9	5.1	5.5	4.2	0.9	2.2	1.3	1.3	2.5	1.4	1.9
26	Other non-metallic mineral products	10.1	6.4	6.2	4.0	3.3	3.3	3.3	7.4	2.7	2.5	1.5	0.9	2.3	1.2
27	Basic metals	3.3	3.3	3.3	3.3	0.9	0.9	3.8	1.2	1.2	1.3	1.5	1.5	1.5	2.7
28	Fabricated metal products	3.8	1.8	1.6	2.8	2.8	1.6	2.2	2.7	1.6	1.5	2.6	2.6	3.4	3.8
29	Machinery and equipment n.e.c.	2.1	12.3	6.7	6.7	1.5	0.0	1.8	2.3	12.3	4.2	4.2	1.8	1.7	1.7
30	Office machinery and computers	1.8	1.8	1.3	1.3	2.1	3.7	3.7	1.7	1.7	1.7	1.7	1.9	1.4	1.4
31	Electrical machinery	3.8	3.8	2.3	5.1	5.3	5.3	4.9	1.5	1.4	1.4	1.8	1.3	1.1	2.3
32	Radio, television and comm. eq.	5.1	4.5	12.9	8.3	7.8	4.5	3.8	1.9	1.4	4.9	1.9	1.9	1.0	0.7
33	Medical and optical instruments	4.2	3.8	4.0	4.1	4.5	2.9	0.6	0.7	0.7	0.7	1.1	1.1	0.9	1.3
34	Motor vehicles, trailers	0.6	0.8	0.8	0.7	0.9	0.9	0.9	1.3	1.7	1.6	1.5	1.5	1.5	1.5
35	Other transport equipment	1.7	1.6	1.1	3.7	1.9	1.9	0.9	3.5	3.4	8.0	7.1	2.8	2.8	1.9
36	Furniture; other manufactured goods	0.9	0.9	0.9	0.9	0.9	0.9	1.0	1.9	2.0	1.9	2.2	1.5	1.5	4.2

Unit: percentage.
Non-EU countries: AUS: Australia; BRA: Brazil; CAN: Canada; CHN: China; IDN: Indonesia; IND: India; JPN: Japan; KOR: Korea; MEX: Mexico; RUS: Russia; TUR: Turkey; TWN: Taiwan; US: United States; RoW: Rest of the World.

Table A.3
Cost of the CBT applied by the EU for each non-EU country considering embodied emissions, 2009.
Source: own elaboration.

Non-EU Country	Country's share of EE-CBT's total collection		Percentage of the value of manufactures exported by any non-EU to the EU		Percentage of the gross domestic product of each country	
Australia	0.3	[14]	1.6	[9]	0.01	[14]
Brazil	0.6	[12]	0.8	[14]	0.01	[13]
Canada	0.7	[11]	1.5	[11]	0.01	[9]
China	29.6	[2]	3.6	[3]	0.16	[1]
Indonesia	0.8	[10]	2.1	[6]	0.04	[8]
India	5.3	[5]	4	[2]	0.11	[7]
Japan	2.4	[8]	1.1	[13]	0.01	[12]
Korea	3.5	[6]	2	[7]	0.12	[5]
Mexico	0.4	[13]	1.5	[10]	0.01	[11]
Russia	5.7	[4]	7.2	[1]	0.13	[3]
Turkey	3	[7]	1.7	[8]	0.14	[12]
Taiwan	1.6	[9]	2.3	[5]	0.12	[6]
United States	7.5	[3]	1.3	[12]	0.01	[10]
Rest of World	38.5	[1]	2.6	[4]	0.13	[4]

Unit: percentage.
Note: Countries ranking: [1] is the most affected country, [14] is the less affected.

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